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(71) Applicants
Michael James Platts, 3 Station Road, Willingham, Cambridge CB 4 5HF,
Michael Joseph French, 4 Haverbreaks Place, Lancaster LA1 5BH
(72) Inventors
Michael James Platts,
Michael Joseph French
(74) Agent
John Edward Alderman, Patents Branch, United Kingdom Atomic Energy Authority, 11 Charles II Street, London SW1Y 4QP, England

(54) Improvements in or relating to a fluid displacement device

(57) A fluid displacement device comprising a tubular tie member 18 of an elastomeric material reinforced with layers 24, 25 Fig. 3 of helically-wound relatively inelastic filaments 23. Adjacent pairs of layers 24, 25 have their filaments 23 wound in opposite-handed relationship to provide a balance between the left hand and the right hand reinforcements of the tie member 18. An outlet valve and an inlet valve are at the respective ends of the tie member 18. When an axial tensioning load is applied to the tie member 18, its bore 21 is reduced in volume to discharge a fluid through the outlet valve and when the load is released, relaxation of the tie member 18 is accompanied by an increase in volume of the bore 21 which allows fluid to be drawn into the bore 21 through the inlet valve.

In one form of the invention the device provides a mooring line 18 for a wave energy converter 10 Fig. 1 so as to pump seawater through a turbo-generator 56 in response to motion of the wave energy converter 10.

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

Fig. 1.

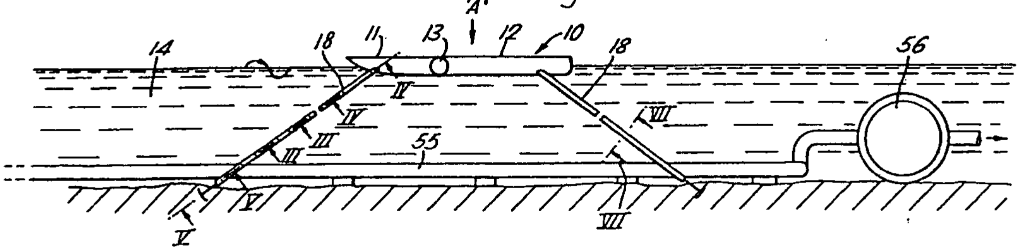
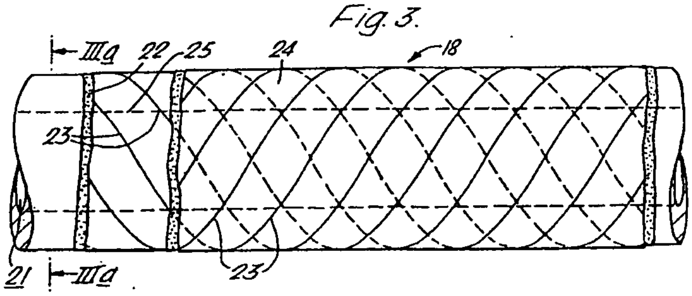


Fig. 3.



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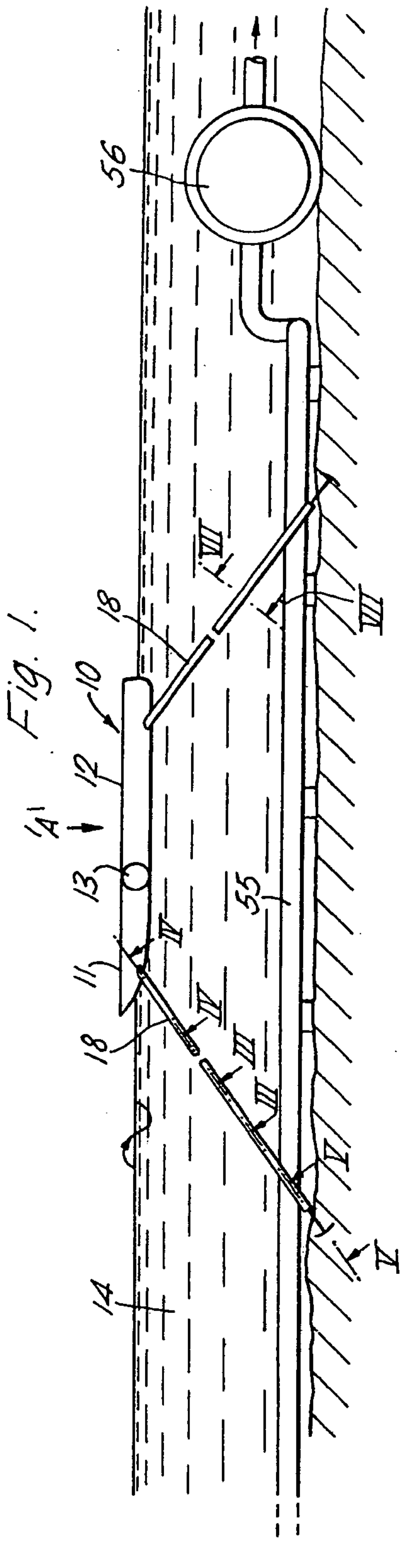

Fig. 1.

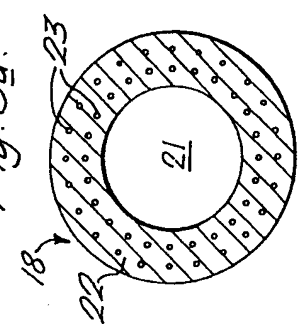

Fig. 3a.

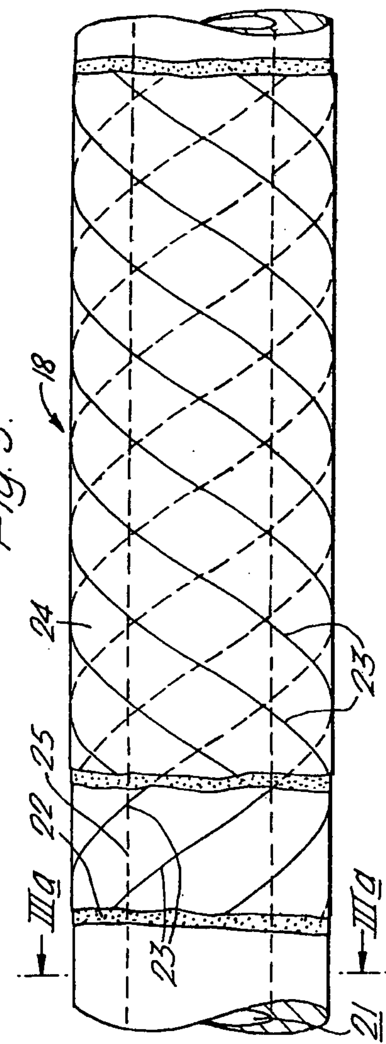

Fig. 3.

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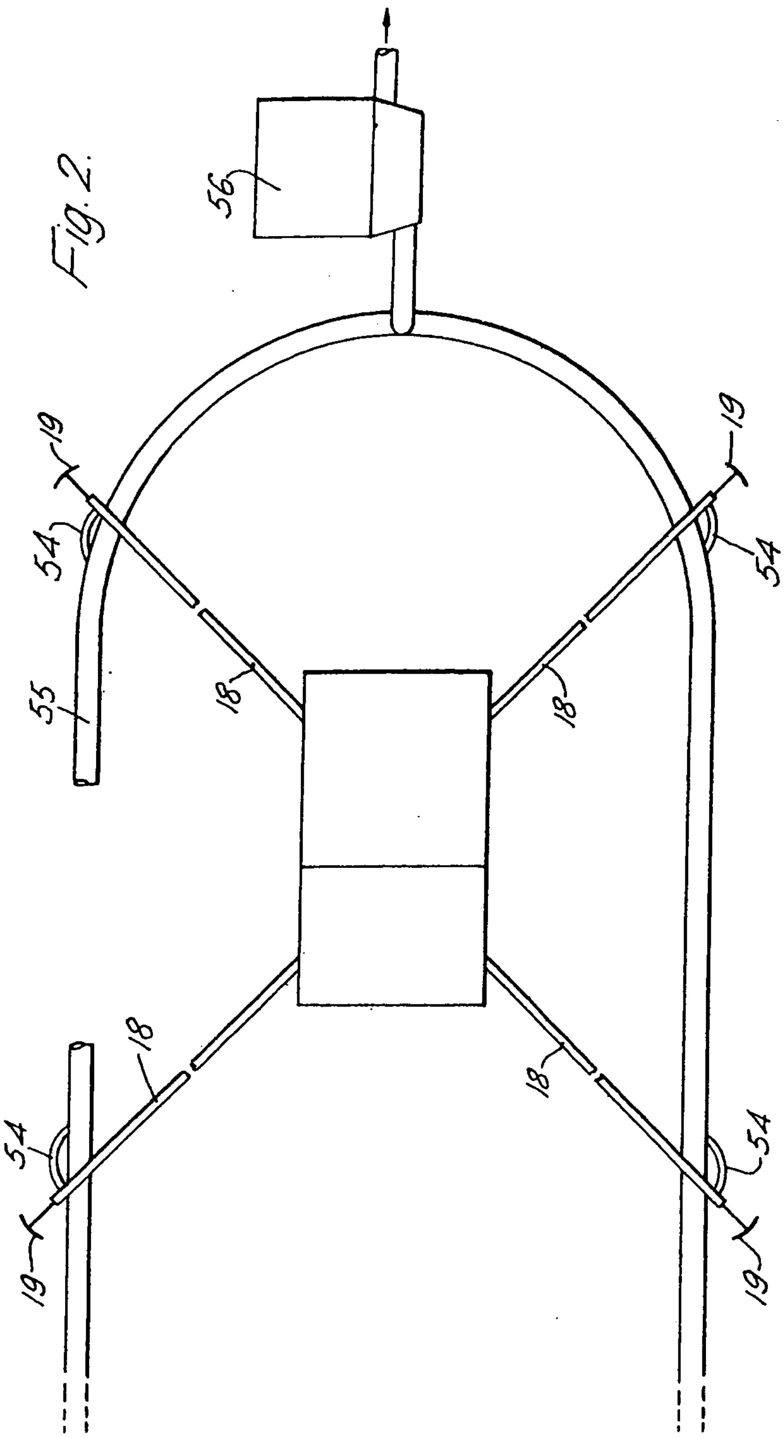
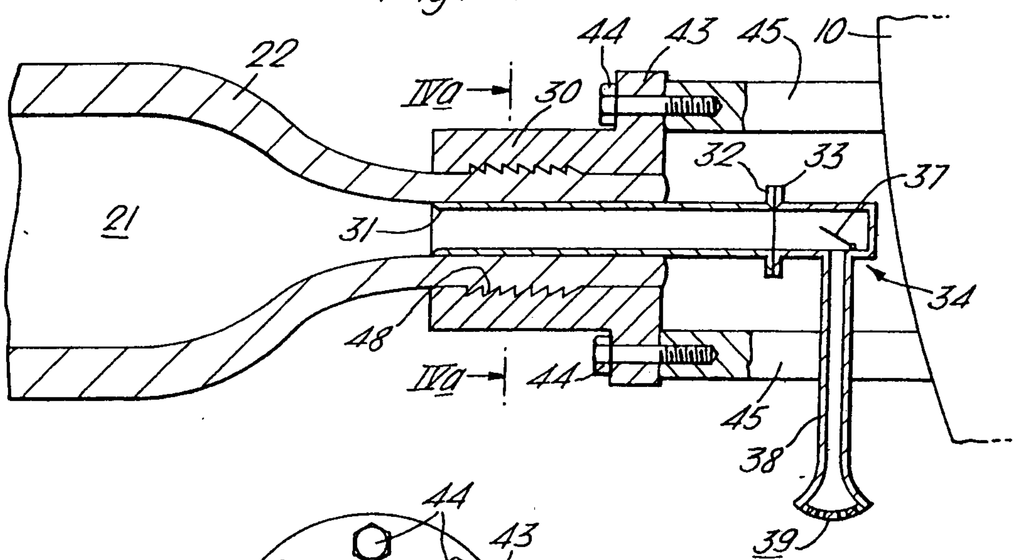


Fig. 2.

Fig. 4.



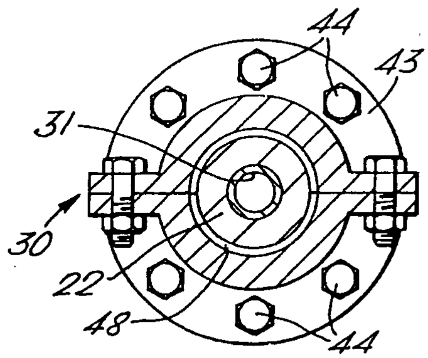
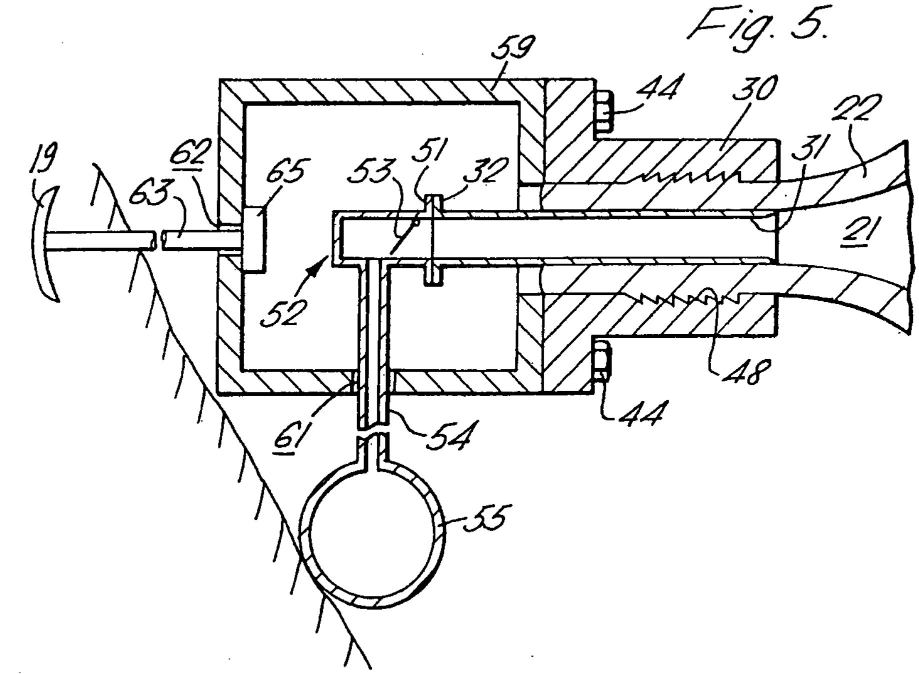


Fig. 4a.

Fig. 5.



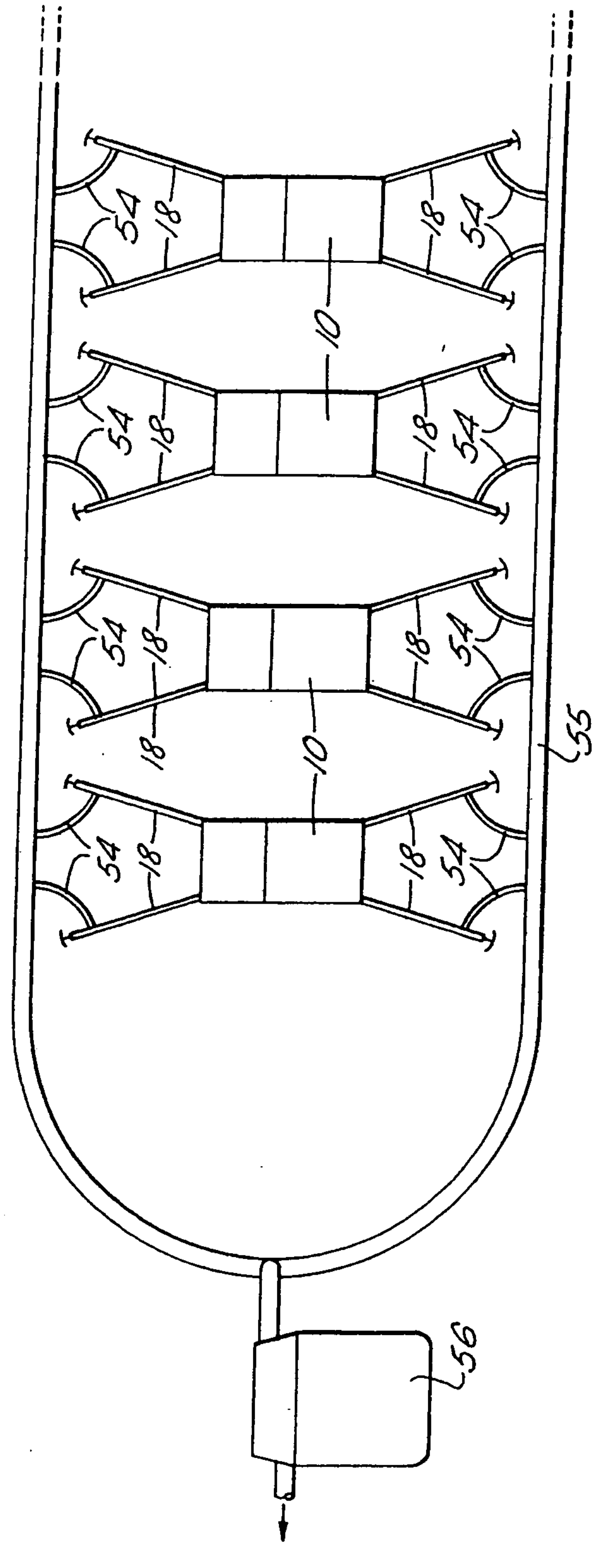


Fig. 6.

Fig. 7a.

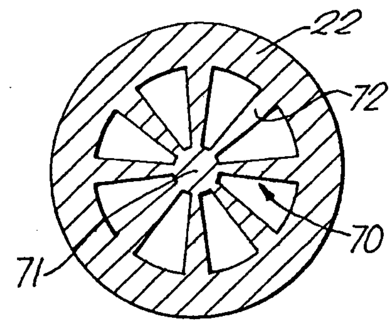


Fig. 7b.

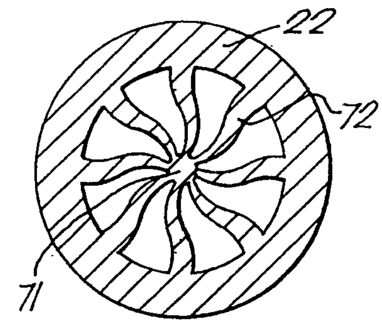
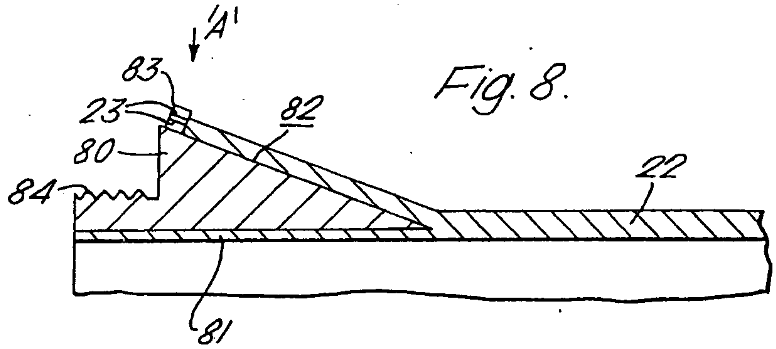


Fig. 8.



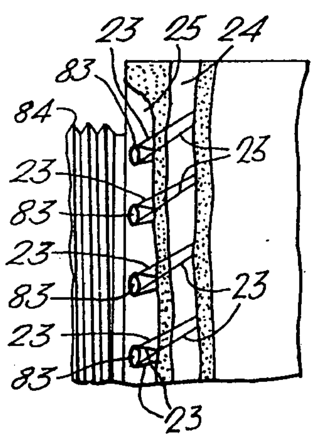


Fig. 8a.

SPECIFICATION

Improvements in or relating to fluid displacement devices

This invention relates to a fluid displacement device and more particularly but not exclusively, to a fluid displacement device for use as a pump.

According to the present invention, there is provided a fluid displacement device comprising a tie member, the tie member comprising a body of elastomeric material and of tubular form so as to define a chamber therein for containing a fluid to be displaced, relatively inelastic filaments incorporated in the body so as to reinforce the body and helically extending along the length of the body in at least two layers thereof radially displaced with respect to each other by the elastomeric material, the filaments in a said layer extending in opposite-handed helical relationship with respect to the filaments in the other said layer, an inlet port and an outlet port for the chamber, whereby subjecting the device to a varying axial load causes radial displacement of the layers and thereby changes in volume of the chamber.

Preferably, the filaments are would at a helix angle with the longitudinal axis of the tie member of about 45°.

The tie member may be reinforced with several said layers of the filaments, adjacent said layers being helically wound in opposite relationship. Alternatively, the several said layers may be an even numbert of said layers arranged in pairs, adjacent said layers in each said pair being oppositely-helically wound, and adjacent pairs having adjacent said layers similarly wound.

Desirably, at least one electrically conductive filament is in the body arranged for monitoring the integrity of the device by a non-destructive testing method.

The invention has one application in which the fluid displacement device comprises a pump, and the pump may comprise a mooring line for a buoyant device, such as a wave energy converter, and arranged to pump seawater in response to motion of the buoyant device. An accumulator may be provided for delivering seawater to the inlet port of the chamber of the mooring line pump, and a plurality of said mooring line pumps may be arranged to discharge seawater into a manifold common to all the pumps and connected to a turbo-generator.

The fluid displacement device may comprise a hydraulic damper or a shock absorber.

The elastomeric material may comprise natural rubber or synthetic rubber, and the filaments may comprise, steel, carbon, natural fibre, rayon, nylon, polypropylene, or glass fibre.

The invention will now be further described by way of example only with reference to the accompanying drawings in which:

Figure 1 shows a side diagrammatic representation of a wave energy converter;

Figure 2 shows a plan diagrammatic representation in the direction of arrow 'A' of Figure 1;

Figure 3 shows to an enlarged scale a fragmentary part-sectional representation on the line III—III of Figure 1;

Figure 3*a* shows a sectional representation on the line III*a*—III*a* of Figure 3;

Figure 4 shows to an enlarged scale a part-sectional representation on the line IV—IV of Figure 1;

Figure 4*a* shows a sectional representation on the line IV*a*—IV*a* of Figure 4;

Figure 5 shows to an enlarged scale a sectional representation on the line V—V of Figure 1;

Figure 6 shows to a reduced scale four of the wave energy converters of Figures 1 and 2;

Figure 7 shows to an enlarged scale a sectional representation on the line VII—VII of Figure 1;

Figure 7*a* shows a sectional representation of the representation of Figure 7 under axial load conditions;

Figure 8 shows in median section a fragmentary view of an alternative representation to that shown in Figure 4;

Figure 8*a* shows in part section a view in the direction of arrow 'A' of Figure 8.

Referring now to Figure 1 and Figure 2, the wave energy converter shown is in the form of a Cockerell Raft 10 which has been described for example in British Patent No. 1448204 and co-pending patent applications No's 7938465 and 7938464 to which reference should be made for further detailed information. Briefly, the Cockerell Raft 10 shown comprises a forward pontoon 11 and an aft pontoon 12 which are hingedly connected together at 13, and when floating in a liquid 14 such as the sea relative movement between the forward pontoon 11 and the aft pontoon 12 in response to waves is used to perform useful work, e.g. actuate hydraulic cylinder (not shown) which is connected to a turbine (not shown). The Cockerell Raft 10 is moored to the sea bed by four liquid displacement devices in the form of mooring lines 18 each attached to a respective anchor 19.

Each mooring line 18 as shown in Figures 3 and 3*a* to which reference is made comprises a tubular body 22 of an elastomer such as natural rubber with a bore 21 and reinforced with a multiplicity of glass fibre filaments 23 arranged in two concentric circular layers 24 and 25 respectively separated by the natural rubber of the tubular body 22. The filaments 23 are wound in a helical manner along the length of the tubular body 22 but those in the circular layer 24 are wound in a right-handed helix whilst those in the circular layer 25 are wound oppositely in a left-handed helix.

Referring now to Figures 4 and 4*a*, the upper end of the tubular body 22 has been pre-stretched and subsequently clamped by a split clamp member 30 onto a tubular metal insert 31 having a flange 32 joined to a corresponding flange 33 of an inlet member 34, the inlet member having an inlet non-return flap valve 37 and an inlet pipe 38 which has a flared partially closed free end to

define a multiplicity of fine apertures 39 to filter the seawater sucked into the bore 21 of the tubular body 22. A flange 43 of the clamp member 30 is secured by screws 44 to threaded spigots 45 extending from the Cockerell Raft 10. In order to improve the grip of the clamp member 30 about the tubular body 22, the inside surface of the clamp member 30 is serrated at 48, and the outside surface of the tubular insert 31 may be similarly serrated (not shown).

At the lower end of each mooring line 18 as shown in Figure 5, the tubular body 22 thereof is provided with a clamp member 30 and a tubular metal insert 31 identical to those fitted at the upper end of the mooring line 18. The tubular insert 31 has the flange 32 thereof secured by screws (not shown) to a corresponding flange 51 of an outlet member 52 having an outlet non-return flap valve 53 and an outlet pipe 54 which is connected to a manifold 55 supported from the seabed and leading to a turbo-generator 56 as shown in Figures 1 and 2 to which reference should be made. The flange 43 of the clamp member 30 is secured to a hollow cylindrical casing 59 having an aperture 61 at one side through which the outlet pipe 54 extends, and a central aperture 62 through which a shaft 63 of the anchor 19 extends and is retained in the casing 59 by an end flange 65.

In operation, relative movement between the forward pontoon 11 and the aft pontoon 12 of the Cockerell Raft 10 in response to waves is used to perform useful work as described in British Patent Specification No. 1448204 and co-pending patent applications No's 7938465 and 7938464 but in addition, the mooring lines 18 are subjected to a varying axial load from the motion of the Cockerell Raft 10 with the result that each mooring line 18 elastically varies in length. This variation is accompanied by consequent straightening and subsequent relaxing of the helically wound relatively inelastic filaments 23 and thus by radial displacement of the layers 24 of filaments 23 which causes a change in volume of the bore 21 of the tubular body 22 of the mooring line 18, the bore 21 performing as a variable volume pumping chamber and discharging seawater through the outlet member 52 into the maniforld 55 on the extension of the mooring line 18 and sucking seawater through the inlet member 34 as the mooring line 18 relaxes. The seawater in the manifold 55 drives the turbo-generator 56 which thus provides an electrical output from the work performed by the mooring lines 18.

A number of Cockerell Rafts 10 may be connected to a common manifold 55 to drive a common turbo-generator 56 as shown in Figure 6 to which reference can be made.

As the mooring lines 18 are relatively elastic they are subjected to considerably lower axial loads as a result of the motion of the Cockerell Raft 10 than would be experienced by conventional cables or chains. This elasticity is a function inter alia of the radial thickness of the elastomer between the layers of filaments, the number of layers and of the filaments in the layers, the helix angles at which the filaments are wound, and the properties of the elastomer and of the filaments. If desired some initial radial stiffness may be incorporated in the tubular body 22 as shown in figures 7*a* and 7*b* by the provision in the bore 21 of an elastomeric member 70 integral with the body 22, and having a central core portion 71 and radial fins 72 extending between the body 22 and the core portion 71, the resistance to distortion of the member 70 as shown in Figure 7*b* providing the required initial stiffness when the mooring line 18 is subjected to an axial load.

Although the invention has been described in relation to the use of two layers 24, 25, of filaments 23, several such layers may be used, for example four layers of filaments 23. It is important to obtain a balance between the pairs of left-hand and right-hand wound filaments in the layers and this can be obtained by adjacent layers being wound oppositely, or for example when four layers are used, by the innermost and the outermost layers being wound in one direction and the intermediate layers being wound in the opposite direction.

In order to maximise the volume change of the bore 21 of the tubular body 22 for pumping, the filaments should be wound at a helix angle with the longitudinal axis of the tubular body 22 below about 55°, a preferred helix angle being about 45°, although other helix angles may be used for specific applications.

The filaments 23 which should be relatively inelastic in comparison with the elastomer used for the tubular body 22, may be metallic (e.g. steel), carbon, natural fibres such as cotton, or plastics such as nylon or polypropylene, as an alternative to glass fibres, the outermost layer of the filaments desirably being embedded in the elastomer so as to be protected by the peripheral portion of the elastomer from the seawater. Alternative suitable elastomers include synthetic rubbers such as Neoprene although natural rubber is preferred since it has superior fatigue properties.

In order to monitor the integrity of the mooring line in use, several electrically conductive filaments (not shown e.g. copper, aluminium) may be incorporated in the tubular body 22 for connection to conventional non-destructive testing equipment.

As an alternative to the use of the split clamp member 30, other arrangements may be used. For example, a clamp (not shown) having semi-circular or quarter-shell taper wedges in an internally tapered collar; or a hollow internal plug (not shown) having a conical outside surface and located in the bore of the tubular body 22, and mating with a collar (not shown) having a tapered bore corresponding to the outside surface of the plug and located about the tubular body 22, the plug and the collar being urged together by screw means (not shown) to compress the tubular body therebetween. A further alternative clamping

arrangement is shown in Figures 8 and 8*a* to which reference is now made.

In Figures 8 and 8*a*, a portion of one end of tubular body 22 is shown having a hollow conical metal insert 80 bonded thereto, a thin tubular portion 81 of the elastomer of the tubular body 22 extending inside the conical insert 80 and the bulk of the elastomer of the tubular body 22 extending over and being bonded to a conical surface 82 of the insert 80. The conical insert 80 is provided at its major diameter with equi-spaced circular pegs 83 extending perpendicularly from the conical surface 82, there being half the number of pegs 83 as there are filaments 23 in a layer 24 or 25 and distributed at a pitch equal to: twice the sum of the diameter of a peg 83 and the diameter of a filament 23. A threaded spigot 84 extends from the conical metal insert 80 to connect the tubular body 22 to another component (not shown). An identical conical insert 80 is provided at the other end of the tubular body 22, and the filaments 23 in each layer 24, 25, are laid by winding a single filament 23 back and forth from one end of the tubular body 22 to the other end and around consecutive pegs 83 at the respective ends of the tubular body 22, the filaments 23 diverging as they wind towards the pegs 83 about that portion of the tubular body 22 that is about the conical surface 82.

It will be understood that alternative conical surfaces 82 may be used, for example of hyperboloidal form.

The mooring line may be used as a force measuring element by determining the pressure at which it discharges seawater since this pressure is a function of the axial load on the mooring line.

Instead of relying entirely upon the recovery of the tubular body 22 to suck seawater into the bore thereof, seawater at low pressure may be supplied to the tubular body from another pump or from an accumulator. Furthermore, by adjusting the pressure in the mooring line the position of the Cockerell Raft may be adjusted.

The invention has been described in relation to a fluid displacement device used as a pump in the form of a mooring line, but the invention can be used to replace a conventional pump, or in other applications, for example as a hydraulic damper or a shock absorber, or, for example the hydraulic cylinder of a Cockerell Raft, a plurality of the fluid displacement devices being disposed above and below the Raft and extending from the forward pontoon 11 to the aft pontoon 12 so as to be alternately stretched and released with relative movement between the forward pontoon 11 and the aft pontoon 12. Alternatively, the fluid displacement device of the invention may be used as an energy extraction system connecting together two bodies one at each end of the displacement device, the bodies being adapted to be moved to and fro by waves on a liquid as described in patent specification No. 2012005A.

The clamping arrangement at the lower end of the tubular body might be designed so as to be uncoupled by use of a tool (not shown) which could be lowered inside the tubular body. The tool could trail a wire (not shown), and the uncoupled tube could be retrieved up the wire, and a replacement tube subsequently fed down the wire and coupled again by the tool.

The mooring line may also be used to discharge seawater to a reverse osmosis desalination plant.

If desired, the inlet valve and the outlet valve may be at the same end of the mooring line, the other end of the mooring line being closed.

The fluid displacement device of the invention might be used to pressurise a gas.

CLAIMS

1. A fluid displacement device comprising a tie member, the tie member comprising a body of elastomeric material and of tubular form so as to define a chamber therein for containing a fluid to be displaced, relatively inelastic filaments incorporated in the body so as to reinforce the body and helically extending along the length of the body in at least two layers thereof radially displaced with respect to each other by the elastomeric material, the filaments extending in opposite-handed helical relationship with respect to the filaments in the other said layer, an inlet port and an outlet port for the chamber, whereby subjecting the device to a varying axial load causes radial displacement of the layers and thereby changes in volume of the chamber.

2. A device as claimed in Claim 1, wherein the body is reinforced with a plurality of said layers of the filaments, the filaments in adjacent said layers helically extending in opposite-handed relationship with respect to each other.

3. A device as claimed in Claim 1, wherein the body is reinforced with an even number of the layers arranged in pairs of the layers, the filaments in adjacent said layers in each said pair helically extending in opposite-handed relationship with respect to each other, and adjacent said pairs having adjacent said layers thereof similarly helically handed.

4. A device as claimed in Claim 3, wherein the adjacent said layers extend at substantially the same helix angle.

5. A device as claimed in any one of the preceding Claims, wherein the filaments extend at helix angle of about 45°.

6. A device as claimed in any one of the preceding Claims, wherein the filaments comprise a metal, carbon, a natural fibre, a plastics material, or glass fibres.

7. A device as claimed in any one of the preceding Claims, including means extending along the chamber for imparting initial radial stiffness to the body but such as to collapse at a predetermined radial pressure.

8. A device as claimed in Claim 7, wherein the means comprises an elastomeric member integral with the body, the member having a central core portion and radially extending fins between the core portion and the body.

9. A device as claimed in any one of the

preceding Claims, including at least one electrically conductive filament in the body arranged for monitoring the integrity of the device by a non-destructive testing method.

10. A device as claimed in any one of the preceding Claims, including at least at one end of the tubular body a relatively inelastic end member of annular form and shaped to provide a spigot portion thereof about which spigot portion the elastomeric material of the body is distributed, and a plurality of anchorages distributed around the outer periphery of the end member for locating respective said filaments thereto.

11. A device as claimed in Claim 10, wherein the spigot portion is of conical form.

12. A device as claimed in Claim 10, wherein the spigot portion has an outer surface of hyperboloidal form.

13. A device as claimed in any one of the preceding Claims, wherein the time member comprises a mooring line for a buoyant device, and the fluid comprises a liquid in which the device is arranged to float.

14. An assembly comprising a plurality of devices as claimed in Claim 13, a manifold common to all the devices and into which manifold each said device is arranged to discharge the liquid, and a turbo-generator arranged to be driven by the liquid in the manifold.

15. A fluid displacement device substantially as hereinbefore described with reference to Figures 1 to 6 of the accompanying drawings.

16. A device as claimed in Claim 15 and modified substantially as hereinbefore described with reference to Figures 7*a* and 7*b*, or Figures 8 and 8*a*, of the accompanying drawings.

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